IWFM Demand Calculator (IDC) Version 4.0

IWFM Users Group Meeting

December 9, 2010

Can Dogrul

California Department of Water Resources

Background

- IWFM Demand Calculator (IDC) is a stand-alone program that simulates land surface and root zone flow processes as well as agricultural and urban water demands under user-specified land-use, soil, climate and farm management conditions
- IDC version 4.0 includes features developed based on CA DWR Bay-Delta Office's experience gained from its own water resources related applications as well as from other groups' applications using previous versions IDC and IWFM
- Although there are previous versions of IDC, IDC v4.0 is the first version that is officially made available to public
- IDC v4.0 is being integrated into IWFM

New Features of IDC v4.0

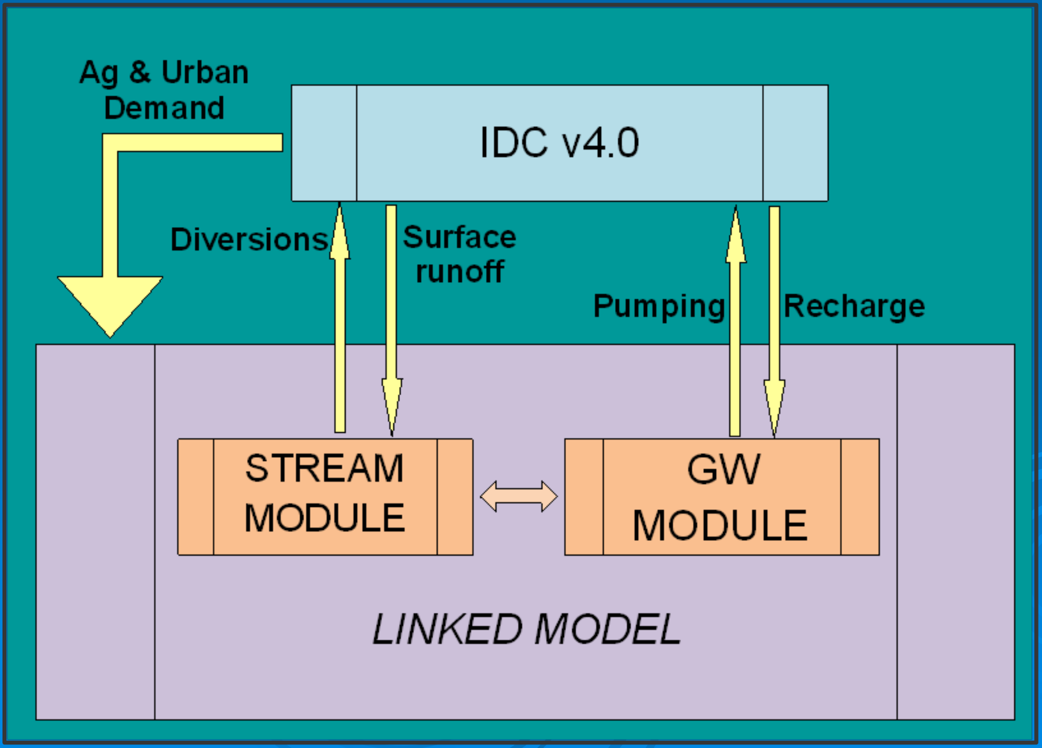
- Use of a computational grid, *finite-element or finite-difference*, to represent spatial distribution of land-use, climatic, soil and farm management properties; each cell can have multiple land-use types specified as time-series data
- Simulation of land surface and root zone flow processes as well as water demand computations are done at each grid cell for each land-use type
- Irrigation-scheduling-type approach at each grid cell for each agricultural crop
- Direct representation of rice fields and refuges
- Ability to simulate regulated deficit irrigation

New Features of IDC v4.0

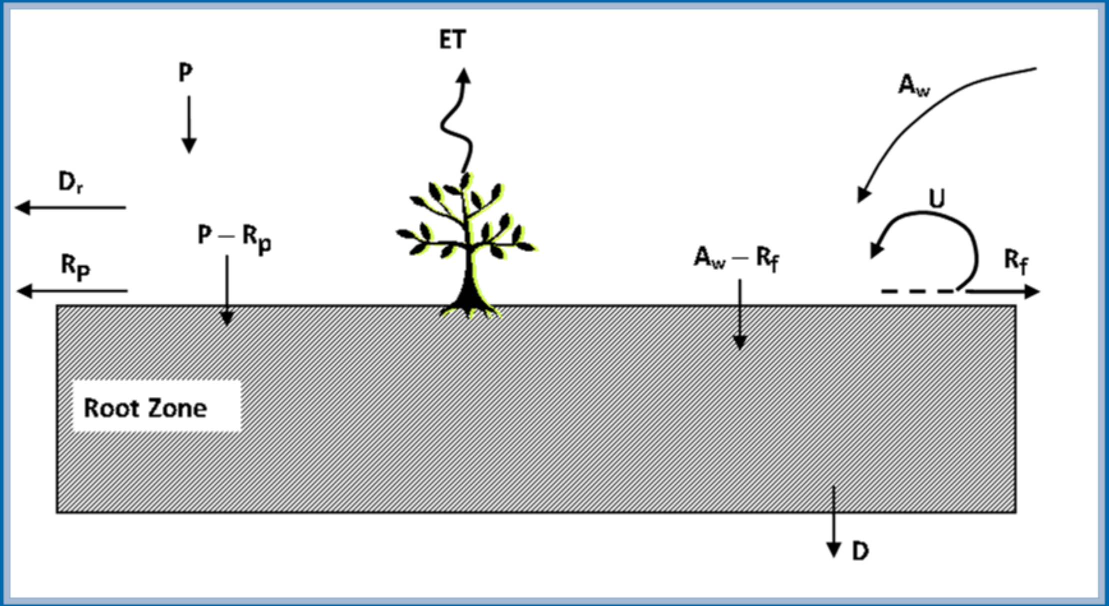
- Urban water demand computation based on population and per capita water usage
- Simulation of ETAW and effective precipitation
- Simulation of re-use of irrigation return flow that takes place at a grid cell, between grid cells or between subregions
- Water demand can be either computed dynamically or can be specified (e.g. contractual water demands) by the user; both options can be used in a single simulation
- Budget output includes soil moisture, and land and water use budgets for individual crops at each subregion

New Features of IDC v4.0

- Available as a stand-alone executable or as a dynamic link library (dll)
- It can easily be linked to finite-element or finite-difference hydrologic models



Schematic Representation of Flow Terms



P = precipitation

A_w = applied water

R_P = direct runoff

U = re-use

R_f = net return flow

ET = evapotranspiration

D_r = drain from ponds

D = deep percolation

Soil Moisture Routing in IDC v4.0

- Governing conservation equation (implicit scheme; all flow terms are computed at time step t+1):

$$\theta^{t+1} = \theta^{t} + \Delta t \left(P - R_P + A_w - R_f - D_r - D - ET \right) + \Delta\theta_a$$

where
θ = soil moisture, [L];
P = precipitation, [L/T];
R_P = surface runoff from precipitation, [L/T];
A_W = applied water, [L/T];
R_f = net return flow of applied water, [L/T];
D_r = pond drainage, [L/T];
D = deep percolation, [L/T];
ET = actual evapotranspiration, [L/T];
$\Delta\theta_a$ = soil moisture change due to changing land use area, [L];
Δt = time step length, [T];
t = time step counter (dimensionless).

Infiltration and Direct Runoff due to Precipitation

$$\theta^{t+1} = \theta^{t} + \Delta t\left(P - R_P + A_w - R_f - D_r - D - ET\right) + \Delta\theta_a$$

- Modified version of the SCS method (USDA, 1985) based on HELP model (Schoeder et al. 1994) to convert event-based approach to time-continious approach

Infiltration and Net Return Flow due to Applied Water

$$\theta^{t+1} = \theta^{t} + \Delta t \left(P - R_P + A_w - R_f - D_r - D - ET \right) + \Delta\theta_a$$

- Applied water is either computed dynamically or user-specified
- Return flow and re-use are computed as user-specified fractions of applied water

Drainage of Rice and Refuge Ponds

$$\theta^{t+1} = \theta^{t} + \Delta t \left(P - R_P + A_W - R_f - D_r - D - ET \right) + \Delta\theta_a$$

- Computed based on user-specified ponding depths:

$$D_r = \frac{P_D^{t} - P_D^{t+1}}{\Delta t} \geq 0$$

where P_D = ponding depth, [L]

Deep Percolation

$$\theta^{t+1} = \theta^{t} + \Delta t \left(P - R_P + A_W - R_f - D_r - D - ET \right) + \Delta\theta_a$$

- Conservation of momentum using van Genuchten-Mualem equation:

$$D = K_u \frac{dh(\theta)}{dz} \cong K_s \left(\frac{\theta^{t+1}}{\theta_T}\right)^{1/2} \left\{ 1 - \left[1 - \left(\frac{\theta^{t+1}}{\theta_T}\right)^{1/m} \right]^m \right\}^2 \quad ; \quad m = \frac{\lambda}{\lambda + 1}$$

where K_s = saturated hydraulic conductivity, [L/T];

λ = pore size distribution index, [dimensionless]

Evapotranspiration (Allen et al., 1998)

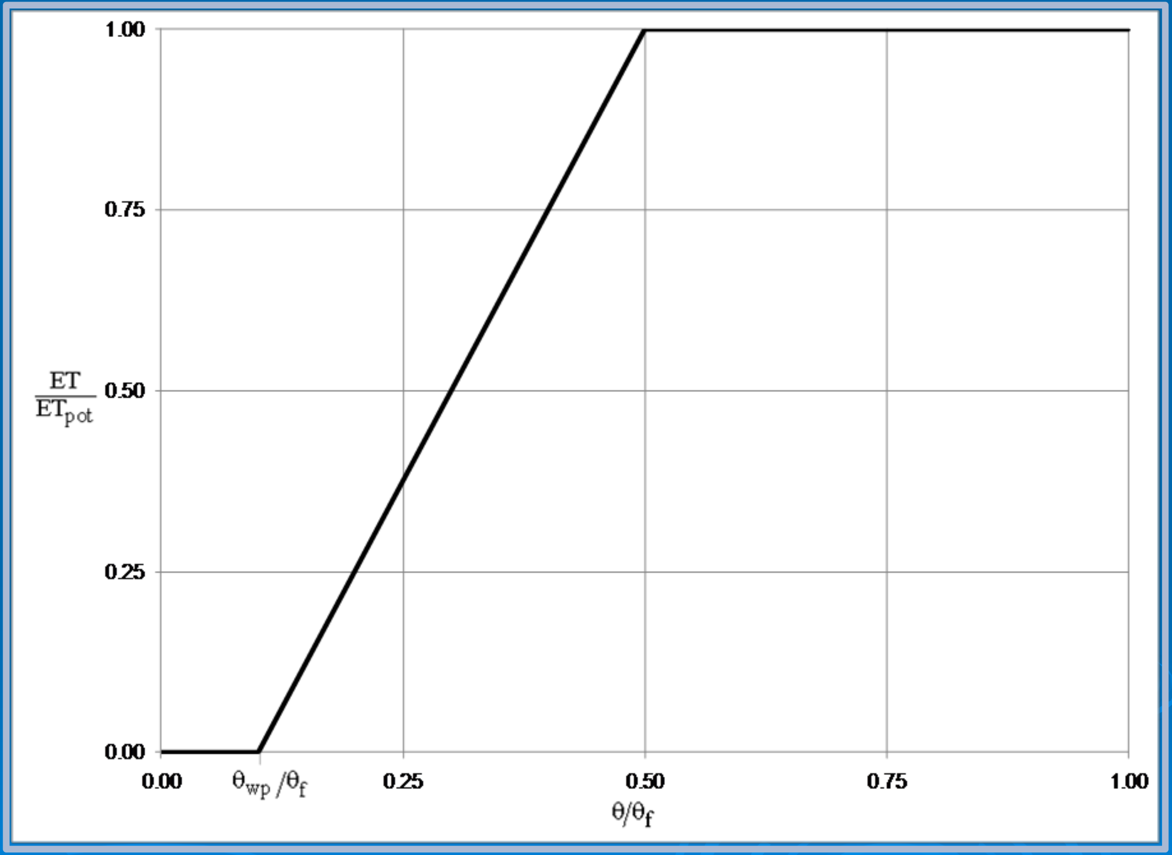
$$\theta^{t+1} = \theta^{t} + \Delta t\left(P - R_P + A_w - R_f - D_r - D - ET\right) + \Delta\theta_a$$

$$ET = \begin{cases} ET_{pot}^{t+1} & \text{if} \quad \dfrac{\theta^{t+1} - \theta_{wp}}{\dfrac{\theta_f}{2} - \theta_{wp}} > 1 \\ \dfrac{\theta^{t+1} - \theta_{wp}}{\dfrac{\theta_f}{2} - \theta_{wp}} ET_{pot}^{t+1} & \text{if} \quad 0 \le \dfrac{\theta^{t+1} - \theta_{wp}}{\dfrac{\theta_f}{2} - \theta_{wp}} \le 1 \\ 0 & \text{if} \quad \dfrac{\theta^{t+1} - \theta_{wp}}{\dfrac{\theta_f}{2} - \theta_{wp}} < 0 \end{cases}$$

Evapotranspiration *(continued)*

Assumptions:

- p is taken as 0.5
- ET_{pot} can be taken as ET_c, ET_{cadj} or whatever is specified by the user



Change in Moisture Due to Area Change

$$\theta^{t+1} = \theta^{t} + \Delta t \left(P - R_P + A_w - R_f - D_r - D - ET \right) + \Delta\theta_a$$

- Introduced to maintain the mass balance when land-use acreages change through simulation period
- When area of a land-use type decreases it is zero
- When area of a land-use type increases, moisture from other land-uses are assimilated and it is non-zero

Agricultural Demand Computation in IDC

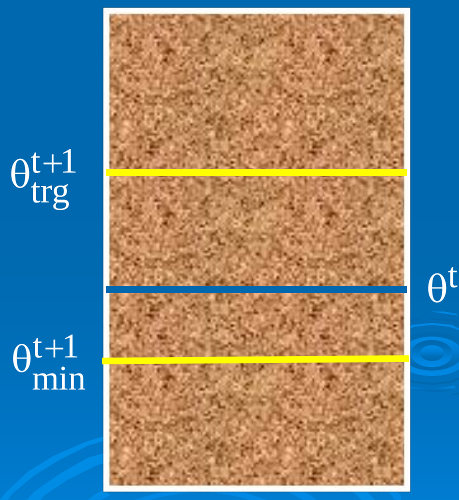
- Physical agricultural demand (computed by IDC)
  - *Non-ponded crops*: required amount of applied water in order to increase the soil moisture to an irrigation target moisture when the moisture falls below a threshold
  - *Ponded crops*: amount of applied water to achieve the required ponding depth or for the decomposition of rice residues
- Contractual agricultural demand (specified by the user) that may or may not be equal to the physical demand

Agricultural Demand Computation in IDC *(continued)*

- Non-ponded crops:

  During an irrigation or pre-irrigation period, IDC checks if moisture content is below a user-specified threshold. If it is, it uses the governing conservation equation to compute A_w that will raise the moisture to a target moisture content:

$$A_w = \begin{cases} \dfrac{\dfrac{\theta_{trg}^{t+1} - \theta^t - \Delta\theta_a^{t+1}}{\Delta t} - P^{t+1} + R_p^{t+1} + D_{trg}^{t+1} + ET_{trg}^{t+1}}{1 - \left(f_{R_{f,ini}}^{t+1} - f_U^{t+1} \right)} & \text{if} \quad \theta^t < \theta_{min}^{t+1} \\ 0 & \text{if} \quad \theta^t \geq \theta_{min}^{t+1} \end{cases}$$



Agricultural Demand Computation in IDC *(continued)*

- Ponded crops:

  During an irrigation or flooded decomposition period, IDC computes A_w to maintain the pond depth at user-specified values:

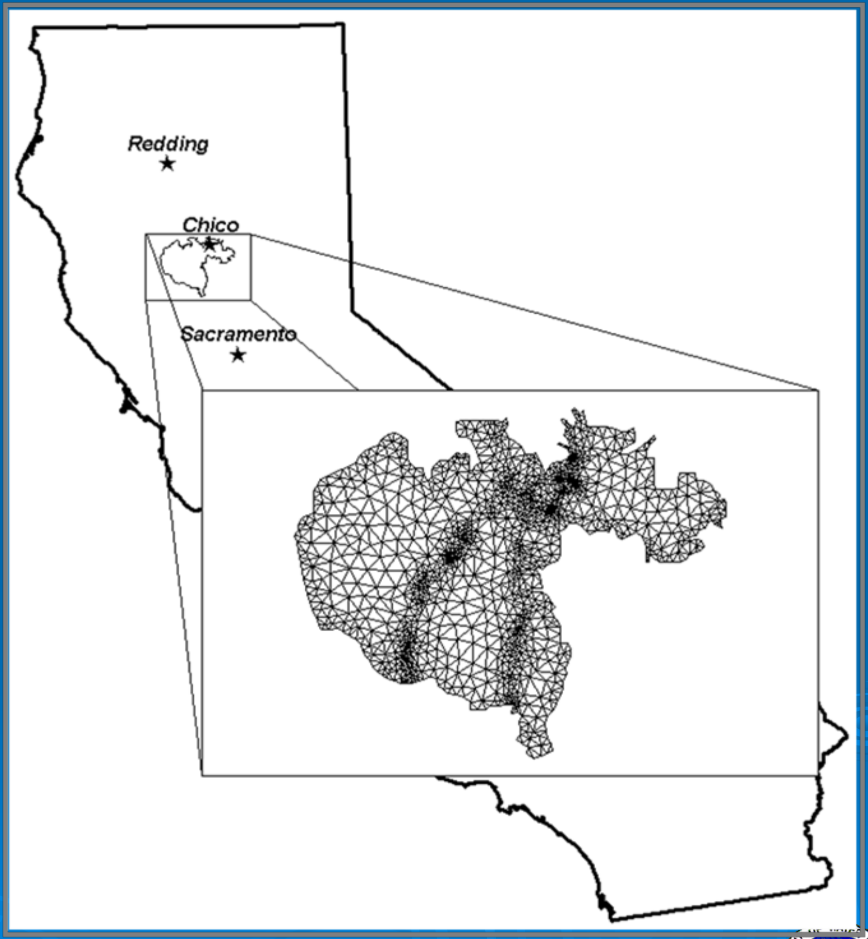
$$A_w^{t+1} = \frac{\theta_T + P_D^{t+1} - \theta^t - \Delta\theta_a^{t+1}}{\Delta t} - P^{t+1} + R_p^{t+1} + K_s + ET_{pot}^{t+1} + R_f^{t+1} - D_r^{t+1} > 0$$

Example

- Four WBAs (7N, 8N, 9 and 10) from CalSim 3.0 are modeled
- Simulation period: WY 1991 through WY 2001
- 20 non-ponded crops (including fallow and idle lands), rice, refuges, urban lands and native vegetation
- Simulation results for WY 1998 through WY 2001 are compared to available values from DPLA (effort concentrated on non-ponded crops and rice separately)
- Most of the input data was adopted from CalSim 3.0 hydrology development project

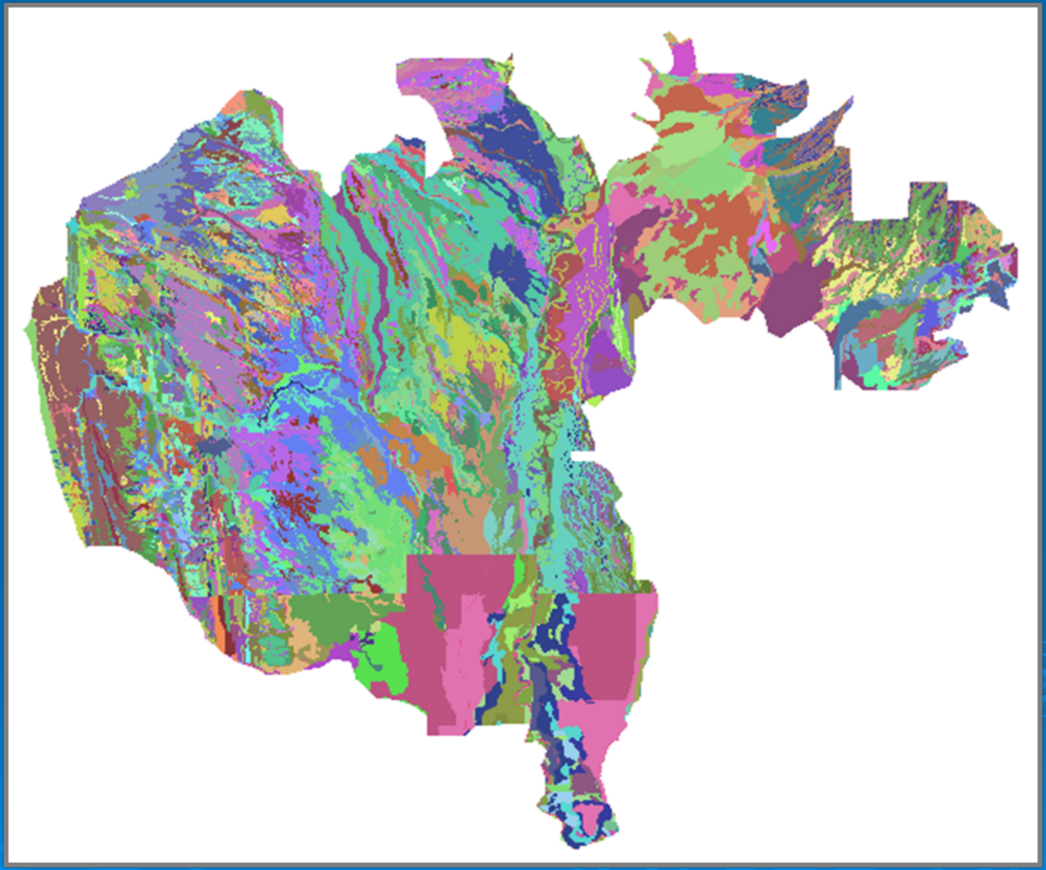
Example – Computational Grid

- 2622 grid cells
- Model area is 1083 mi^2
- Average cell area is 0.4 mi^2



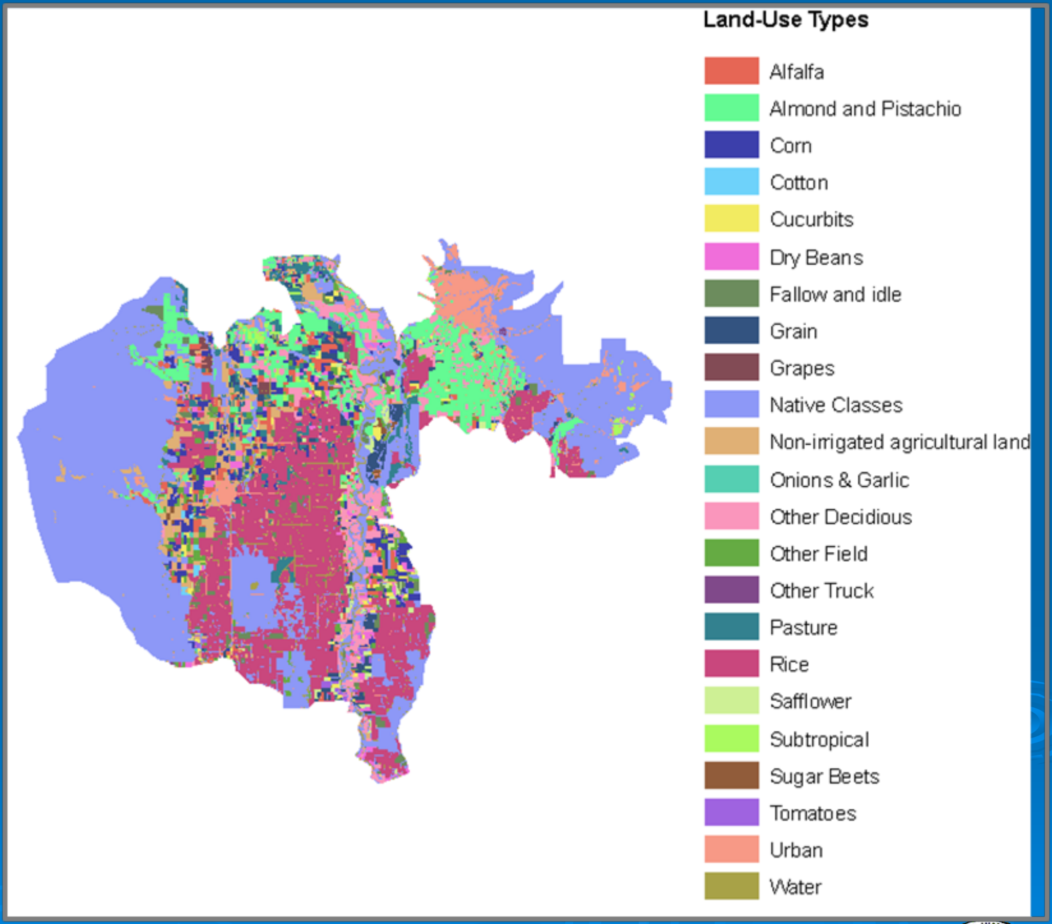
Example – Soils

- NRCS SSURGO soils database is used to calculate soil physical properties for each grid cell



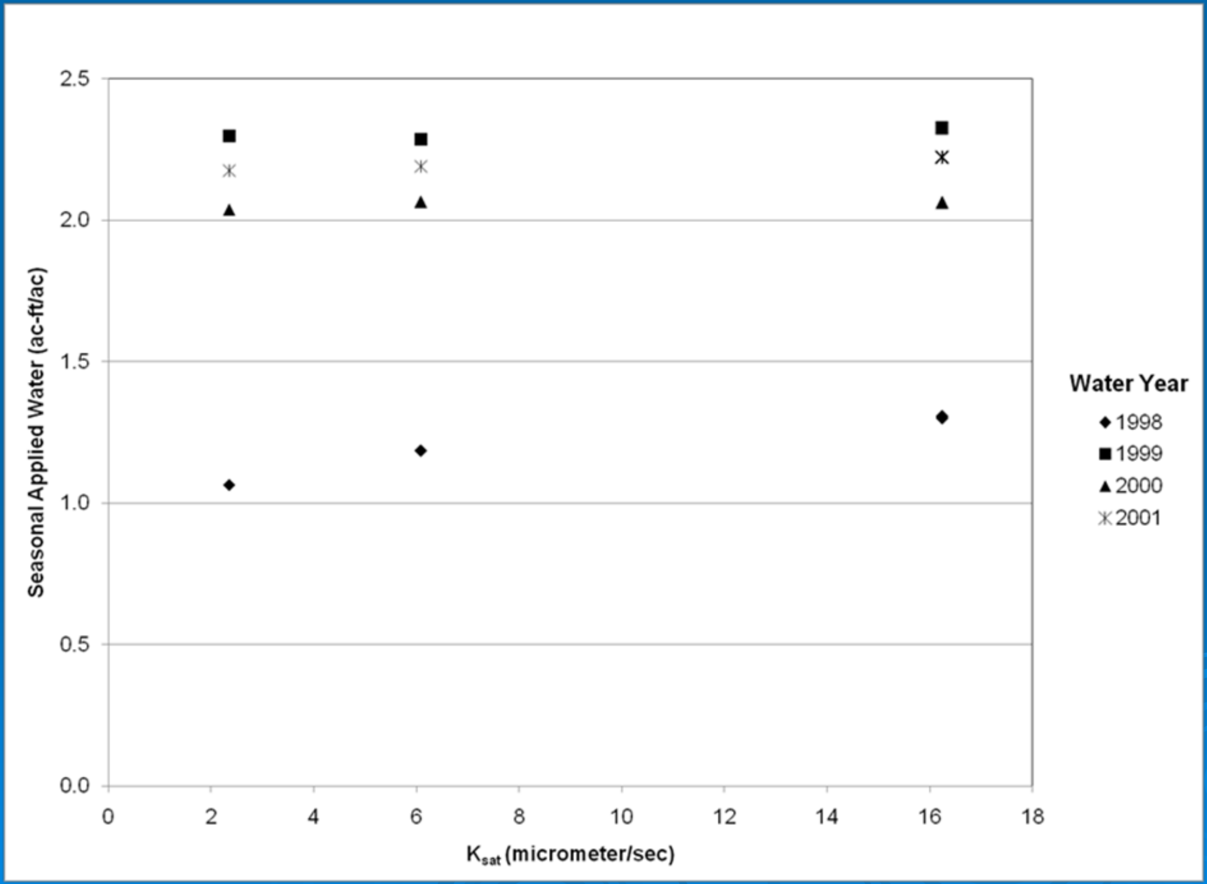
Example – Land-Use Types

- DPLA land-use map for year 2003 was used
- Water (2% of total model area) and non-irrigated agricultural lands (4% of the total model area) were combined into native vegetation lands



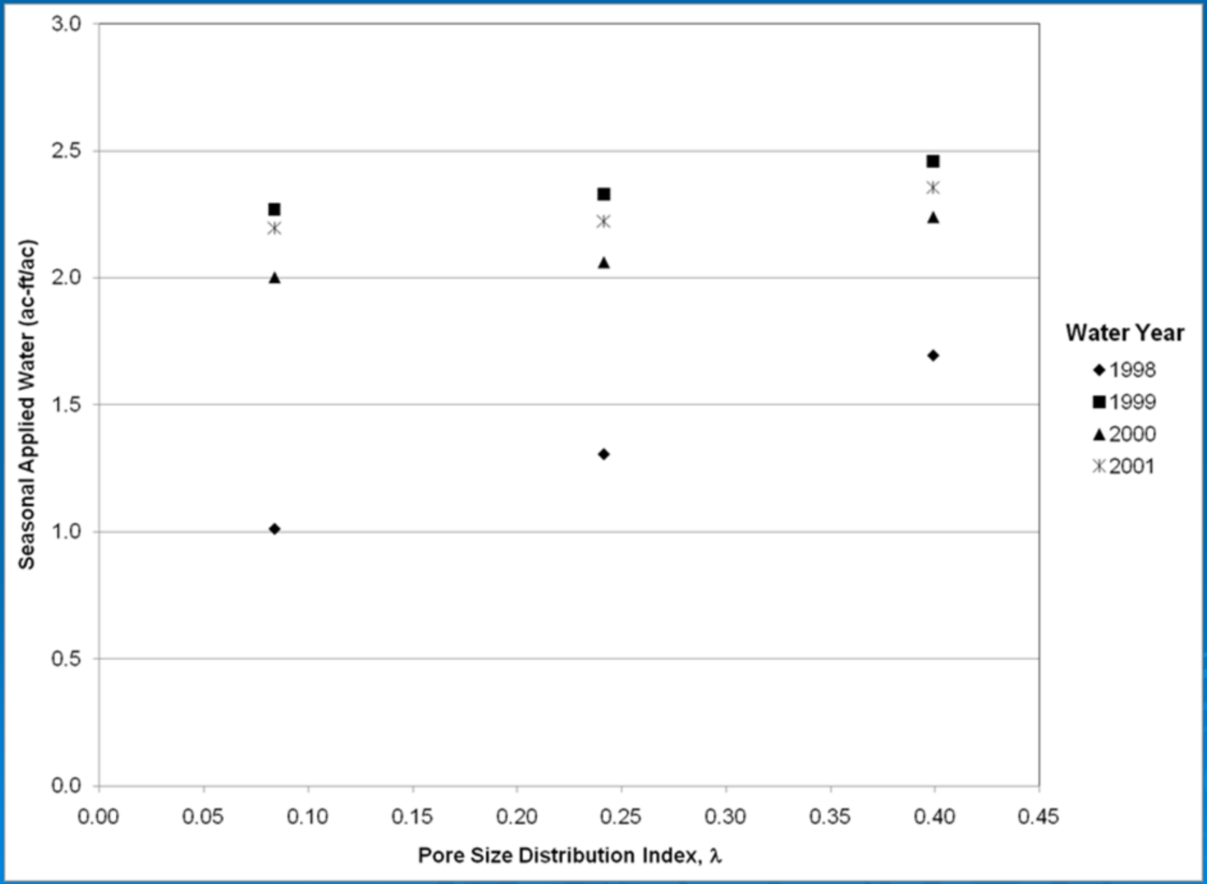
Example – Sensitivity to K_{sat} for Non-Ponded Crops

- A_w for non-ponded crops is not very sensitive to K_{sat}



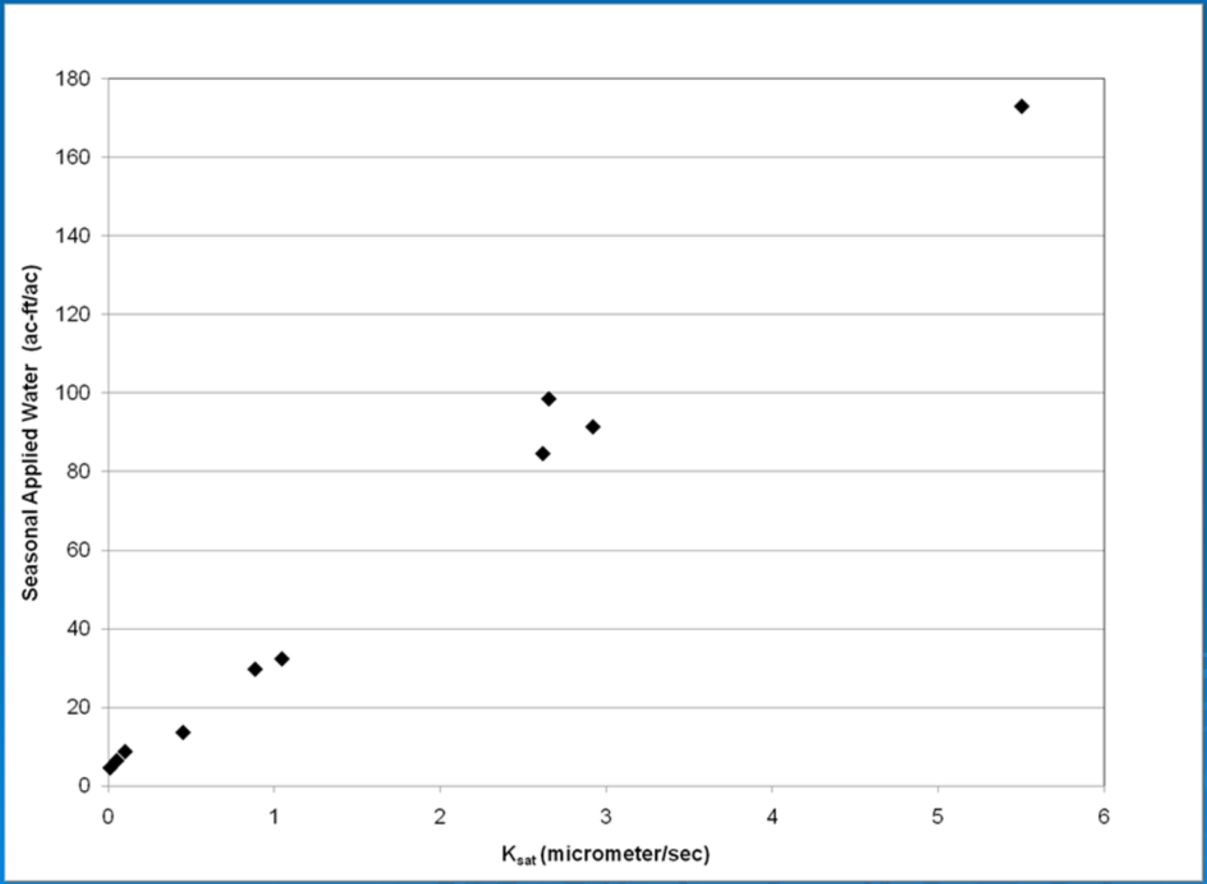
Example – Sensitivity to λ for Non-Ponded Crops

- A_w for non-ponded crops is more sensitive to λ



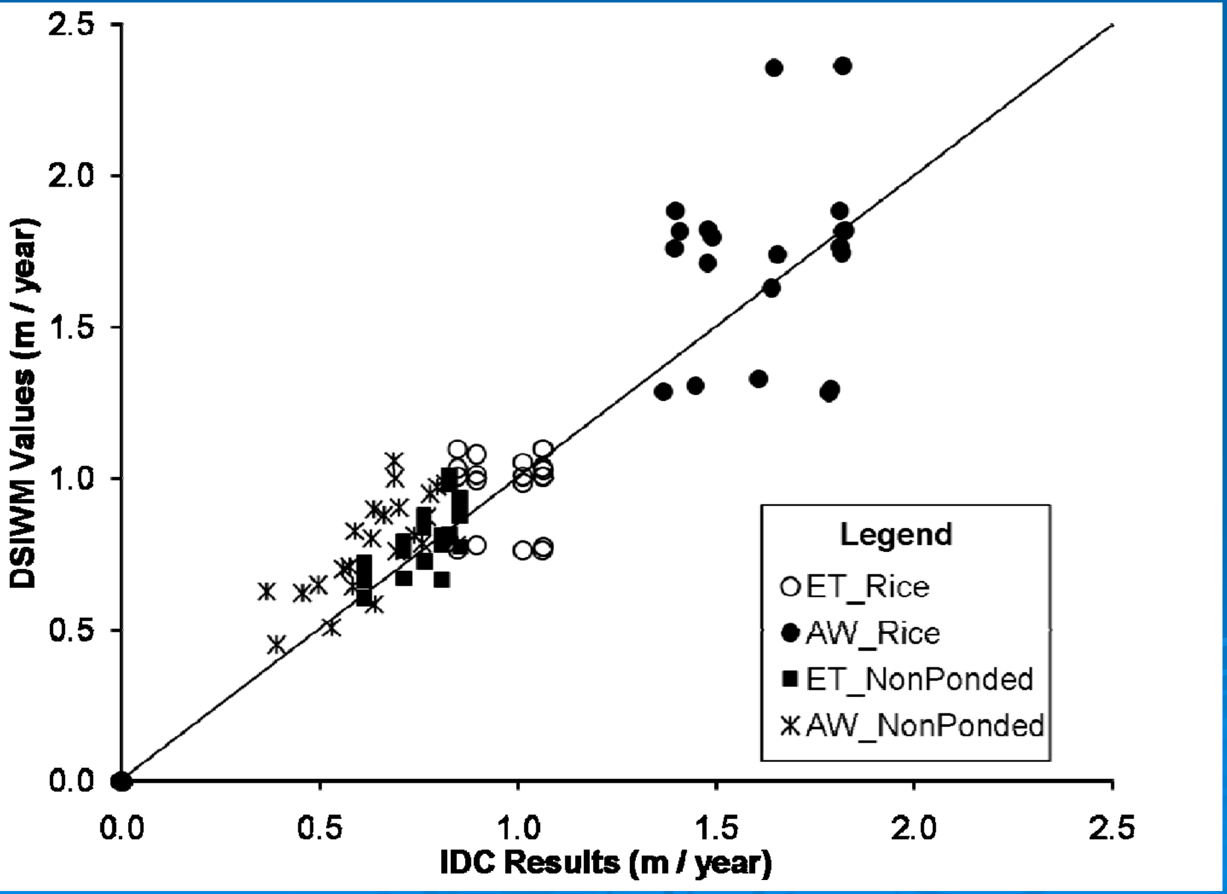
Example – Sensitivity to K_{sat} for Rice

- A_w for rice is very sensitive to K_{sat}



Example – Comparison to DSIWM Values
(with K_{sat} = 0.01 μm/sec at cells with rice)

- With minimal effort and no calibration, IDC values are reasonably close to DSIWM values



Example - Conclusions

- A_w for rice is very sensitive to K_{sat} and has zero sensitivity to λ
- A_w for non-ponded crops is not very sensitive to K_{sat} but sensitive to λ
- For proper simulation of A_w and deep percolation, calibrate K_{sat} for rice and λ for non-ponded crops
- Compared to DSIWM values, IDC seems to generate reasonable results given that precipitation, crop acreages and input ET values are different between IDC and DSIWM

Final Remarks

- IDC v4.0 executables, source code and documentation are available for download at the DWR's IWFM web site
- IDC v4.0 is being integrated into IWFM which will be released as IWFM v4.0

Questions?